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## Drivers of cycling mode-share: analysis of danes travel behavior 1996-2013

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### Abstract

Denmark, as Europe's second cycling nation after the Netherlands, has a cycling mode share of around 15% of all trips. Cycling was decreasing slowly through the 1990s into the 2000s, which inspired substantial investments and promotional efforts to reverse the trend. This paper uses Danish micro-level travel survey data series from 1996 through 2013 to analyze the trend in cycling as main or access mode, as well as the significance of background variables representing key spatial and societal trends. The analysis confirms that the general trend in cycling from 1996 to 2013 was negative irrespective of statistical control for socio-economics, ageing, location, urban density, and weather. Results point to an increasing significance of population density over time as well as changes to the effect of location vis-à-vis the largest urban centers. The difference in cycling between central areas and more peripheral areas is growing. Other changes include a decreasing 'income divide' in cycling as well as a decreasing retirement effect. Results are presented and discussed.

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**Keywords:** Cycling; location; time trend; Denmark; travel survey; mode share; drivers

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## 1. Introduction

Cities around the world have increasingly turned to cycling as a sustainable travel mode that provide mobility while also having beneficial effects on public health. Denmark is known as Europe's second cycling nation with a mode share hovering around 15% of all trips by the adult population (Nielsen et al. 2013 a) and a use pattern which is based mainly in utility/ everyday cycling in urban settings (Nielsen. 2013 c).

The mode share was found to be decreasing through the 1990s into the 2000s, paving the way for substantial investments and promotional efforts from the late 2000s with the aim of maintaining and increasing cycling for its public health benefits and as a contribution to sustainable transport (Goeverden et al. 2015). Analysis has pointed to a slow 10% decrease in cycling from the middle of 1990s to 2013 with significant differences between municipalities/geographical areas. Some central areas have growing cycling mode shares whereas especially metropolitan peripheries tend to experience declining use of bicycles (Nielsen et al. 2013 b; 2014).

Few studies have looked into the time trends in cycling and their associated drivers. Exceptions include Goeverden et al. (2013), and Harms et al. (2014) whom relied on the Dutch national travel survey to elaborate trends and their correlates. More general studies have looked into selected indicators (e.g. Wardlaw, 2014), but will be lacking in linking change in cycling to underlying changes in location patterns and demographics. This paper aims to add to the state of knowledge by studying the changes in cycling mode share in Denmark, specifically addressing the geographical differences of the development as well as the wider set of demographical, socio-economical and structural conditions contributing to changing cycling mode share.

Cycling has been shown to be significantly affected by weather and season (Christensen and Jensen, 2008) (Figure 1). Trend and change analysis requires controlling for these effects to reduce 'noise' and avoid potentially erroneous conclusions due to extended periods with mild winters.

The paper assembles and exploits Danish micro-level travel survey data series covering 1996-2013 to analyze the trend in cycling as main or access mode, as well as the significance of background variables representing key spatial and societal trends. In addition to a time trend the analysis considers age, occupation, form of residence, household type, gender, income, urban density and regional location, weather, and ticket and fuel price indicators.

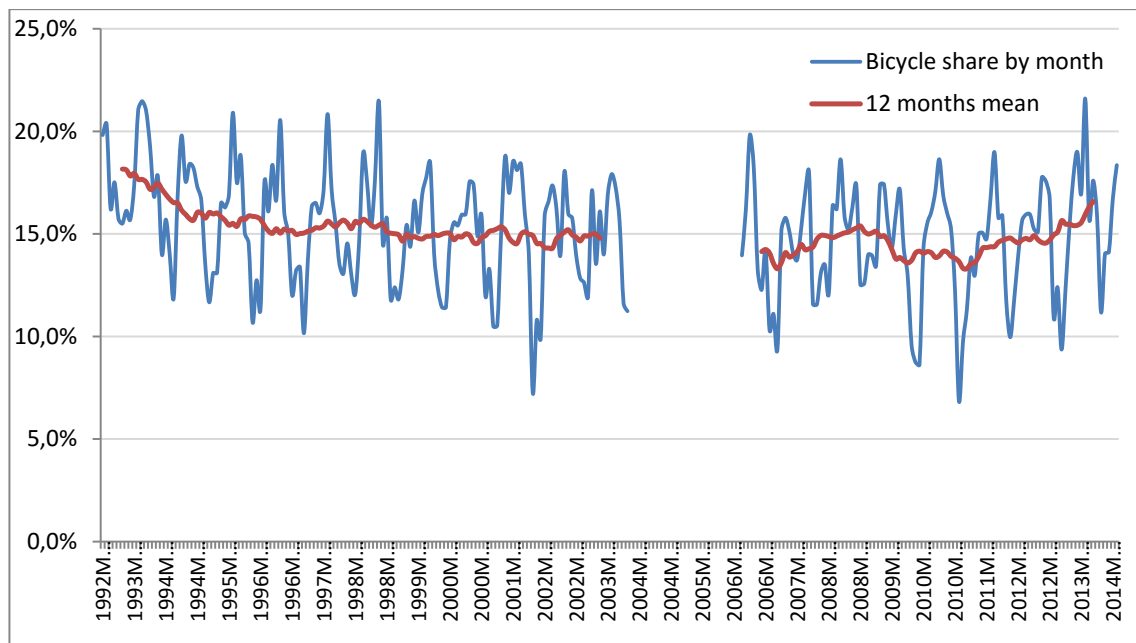


Fig. 1. Danish National Travel Survey (TU), monthly averages of bicycle mode share in all trips by age group 16-74, Danish residents, N=747633 trips.

## 2. Methodology

The methodology is based on joint use of Danish National Travel survey data 1992-2003 and 2006-2014 to support the analysis of trend changes and interactions. Access to spatial data and cost indicators limits the available time series to the period 1996-2013 (including 1996 and 2013, but excluding two years in the middle: 2004 and 2005). The available survey population through the 1996-2013 period is the age group 16-74.

As policy interests in the promotion of cycling involves cycling as main mode as well as cycling in combination with public transport the dependent variable was specified based on whether a bicycle was used on a trip or not (no bicycle use: 0, bicycle use: 1)

Independent variables included: year (time trend), week-day, age, occupation, form of residence, ownership of residence, household type, gender, income, regional centrality, population density, weather, and price-indexes. Including a long time series in the analysis to adequately address the trend and its changes has been a priority. This involves tradeoffs vis-a-vis the availability of variables for analysis. E.g. the level of education is not available in the first years of the travel survey and limits the possibilities of trend analysis when included (availability of variables in resent TU, see: Christiansen and Skougaard, 2015).

Regional location, city size and population density were measured based on respondents municipality of residence. The 278 municipalities from the previous municipal reform (1970-2007) were used as spatial entities. This imply that the spatial variables are generally measured at the city level – or in the case of the greater Copenhagen area – for administrative subdivisions that encompass several neighborhoods. Measures included distance to the centers of the two main metropolitan areas: Copenhagen and Århus, city size measured as urban population, and density measured as the average population density in the urban zones.

Weather variables were assigned to respondents based on municipality of residence and its location vis-a-vis prevalent climate zones (fronts/weather systems passing from west to east), available weather stations from the Danish Meteorological Institute (DMI) and their associated time series of measurements (Cappelen, 2014). Each trip in the travel survey data was assigned weather data recorded on the travel day (day precipitation, max and minimum temperatures) as well as records of frost and precipitation within 3 and 7 days up to the day of travel.

Direct variable costs of transport were included in the analysis based on monthly price indexes for motor fuel and travel by rail (Danmarks Statistik, 2015). Prices as represented by the indexes are thus the same for all Danes, but vary over time.

Combining spatial data, weather data and TU variables the result is a database of trips with relevant explanatory variables covering 1996 to 2013. Analysis of the use of bicycles on trips were conducted based on logit analysis with additive effects as well as interactions between explanatory variables and time trend to target changes in cycling correlates over time.

## 3. Results

The results points to effects of gender, age, income, city size, regional location, weekday, form of residence, ownership of residence, occupation, and weather on cycling. Vehicle fuel and public transport ticket cost variables are both positively correlated with the probability of cycling but only the costs of public transport appear to be statistically significant. Increasing public transport travel costs increases cycling mode share. As national monthly indexes both cost indicators are in poor spatial and temporal resolution for micro-level analysis and the results are sensitive to changes in the model specification. This is an important 'topic' for the analysis as not all variables are available for the full time-series. For instance data on education is only available in the second half of the time-period, but is known to be strongly correlated with cycling. Thus testing of the robustness of the conclusions given different lengths of time-series and control-sets has been carried out.

The analysis confirms that the general trend in cycling from 1996 to 2013 was negative – irrespective of statistical control for socio-economics, ageing, location, weather etc. Estimation of effects on a yearly basis confirms a relatively monotonous decline in the *ceteris paribus* time-effect on the probability of cycling on a trip.

Analysis of interaction effects points to an increasing significance of city size for cycling over time as well as changes to the effect of location vis-à-vis the largest urban centers. The differences in cycling between large urban areas and the more rural areas is growing substantially over time - additionally the peripheries of the largest

metropolitan areas experiences decreasing cycling over time, due to increasing travel distances and integration into a larger urban region. Thus, cycling growth in the largest cities is paralleled by a ‘backside’ of absolute and relative decline in rural areas and other parts of the growing functional regions.

Other interaction effects points towards decreasing negative effects of retirement/ageing on cycling as well as decreasing negative effects of income levels. Thus retirees are generally cycling less than younger adults but the difference is decreasing. One likely explanation for this is that the average health condition of a retiree has improved over the years. For income high earners are generally less likely to bicycle than others but this effect has also decreased over the years. This may again indicate that the high earners have responded stronger to the recent years efforts to promote and sustain cycling in the Danish population.

#### 4. Conclusion

The paper used Danish micro-level travel survey data series from 1996 through 2013 to analyze the trend in cycling as main or access mode, as well as the significance of background variables representing key spatial and societal trends.

The analysis confirmed that the general trend in cycling from 1996 to 2013 was negative irrespective of statistical control for socio-economics, ageing, location, urban density and weather.

A wide set of socio-economic, demographic, location, costs, and weather are significant correlates of the probability of cycling across the sample.

Focusing on the correlates that were studied for their changes over time the results points to an increasing significance of population density as well as changes to the effect of location vis-à-vis the largest urban centers. The differences in cycling between large urban areas and the more rural areas are growing as is the differences between central areas and the metropolitan peripheries.

Additional results points to the changes associated with retirement and a ‘bend’ to the significance of income. Retirees are less likely to cycle, but this difference is decreasing as the average health condition of the older populations in improving. High earners are also less likely to cycle but this difference is also decreasing over time – indicating a stronger responds among the high earners to cycling promotion.

The negative trend in cycling as well as the growing center-periphery difference is problematic from the perspective of cycling promotion as a contribution to public health. The negative trend may be taken as an indication of the presence of life style factors that are not represented by the other variables, which develops towards a state where bicycles are less competitive. The center-periphery indicate that there are geographies that requires special attention to maintain and increase cycling and especially release its public health benefits as they rely on a wide adoption in the population. Changes to the income correlation of cycling mode share could indicate that the social profile of cyclists is gradually dissolving. If this is the case it may be positive, but additional studies will be required to target whether it is the more well off that increasingly adopts, or the less well off that increasingly abandon cycling.

The data and methodology presented may be seen as proof of concept for an alternative use of travel survey data to support the assessment of interventions such broad national campaigns and the Danish governments programme ‘Cykelpuljen’ to support cycling infrastructures and promotion (2009-2015).

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